Geiger-mode Avalanche Photodiodes as photodetectors in Cherenkov astronomy

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Motivation

Requirements for Cherenkov astronomy:

- Sensitivity (few photons, spectrum peak at 350 nm)
- Speed
- Ease-of-use (reliability, stability, ruggedness...)

PMT

+ very sensitive
+ fast
+ proven technology
– fragile

G-APD

+ even more sensitive
+ faster, smaller transit time spread
+ very reliable
+ no high voltage necessary
– still expensive
– (almost) all parameters temperature dependent

$\Rightarrow$ The use of G-APDs as photodetectors in an IACT is currently being investigated in the FACT project (First G-APD Camera Test).

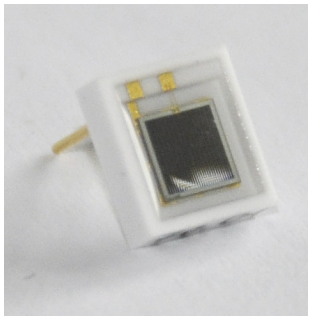
Basic properties

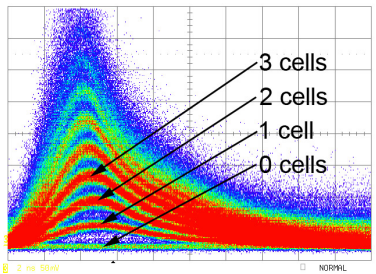
G-APD = Geiger-mode Avalanche Photodiode

also called SiPM, MPPC, PPD...

- Pixelized photon detector: each cell can detect single photons, the total signal is the sum of the identical single cell signals
- Gain $10^5 - 10^7$
- Photon detection efficiency (PDE) $30 - 50\%$
- Statistical saturation
- Very stable, no aging found
- Several manufacturers: CPTA/Photonique, Hamamatsu, MPI Semiconductor Lab, Zecotec...

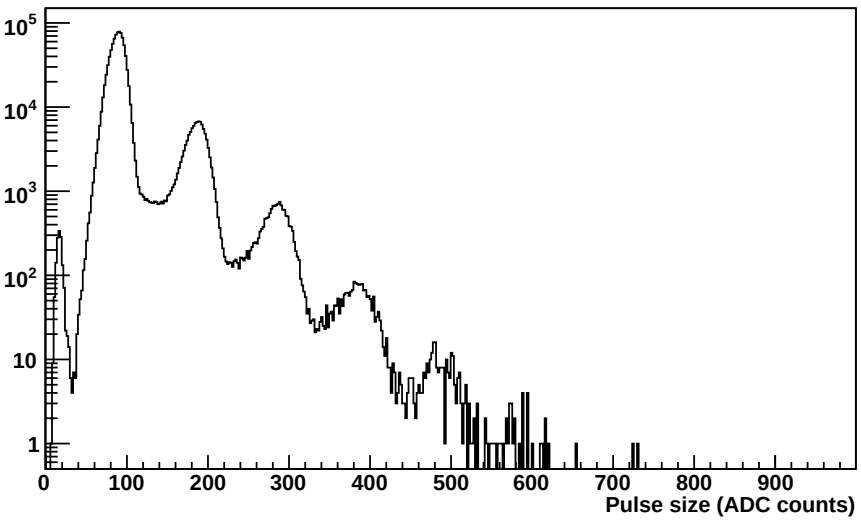
More information: see eg. D. Renker & E. Lorenz, JINST 4 P04004, (2009).





Crosstalk, dark counts and afterpulses: spectrum

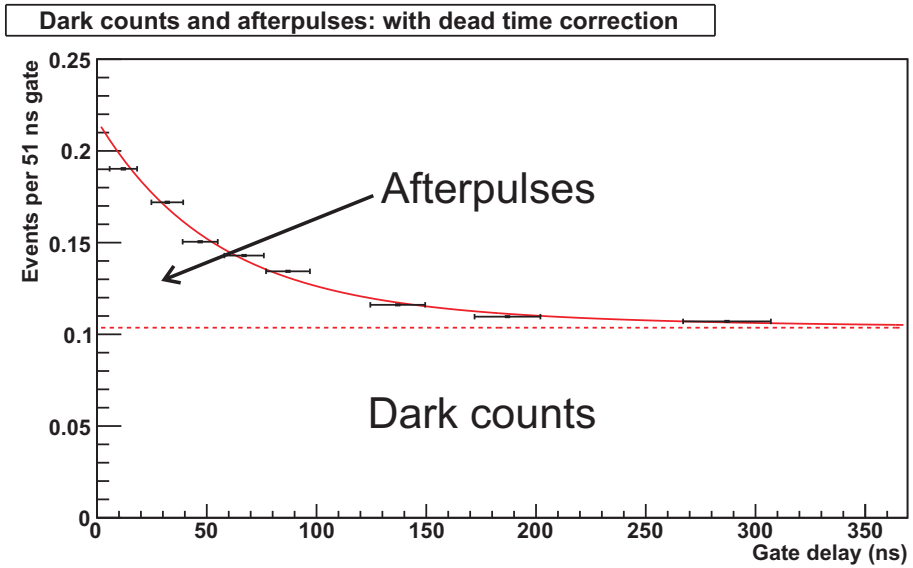
- Dark counts: Cells can be triggered by any free carrier, eg. thermally generated or field assisted tunneling.
  - Rate: some 100 kHz up to MHz per mm^2 at room temperature.
- Afterpulses: The delayed release of carriers trapped during a breakdown in a cell can trigger the cell again.
  - Afterpulse probability $5 - 20\%$ depending on the gain.
- Crosstalk: A cell in breakdown emits photons which can trigger neighbouring cells.
  - Defines the spectrum of the two phenomena above.
  - Crosstalk probability $5 - 20\%$ depending on the gain.



Measured spectrum of dark counts and afterpulses (crosstalk 13%). Peaks up to 6 triggered cells can be discerned.

Dark counts and afterpulses: timing

- Dark counts have a random time distribution.
- Afterpulses have an exponentially decreasing probability after an initial breakdown.



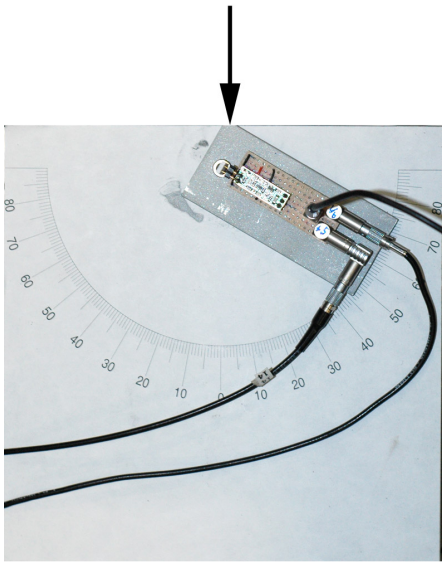
Number of pulses per gate for variable delays after an initial pulse. The number of pulses decreases exponentially to the level of dark counts.

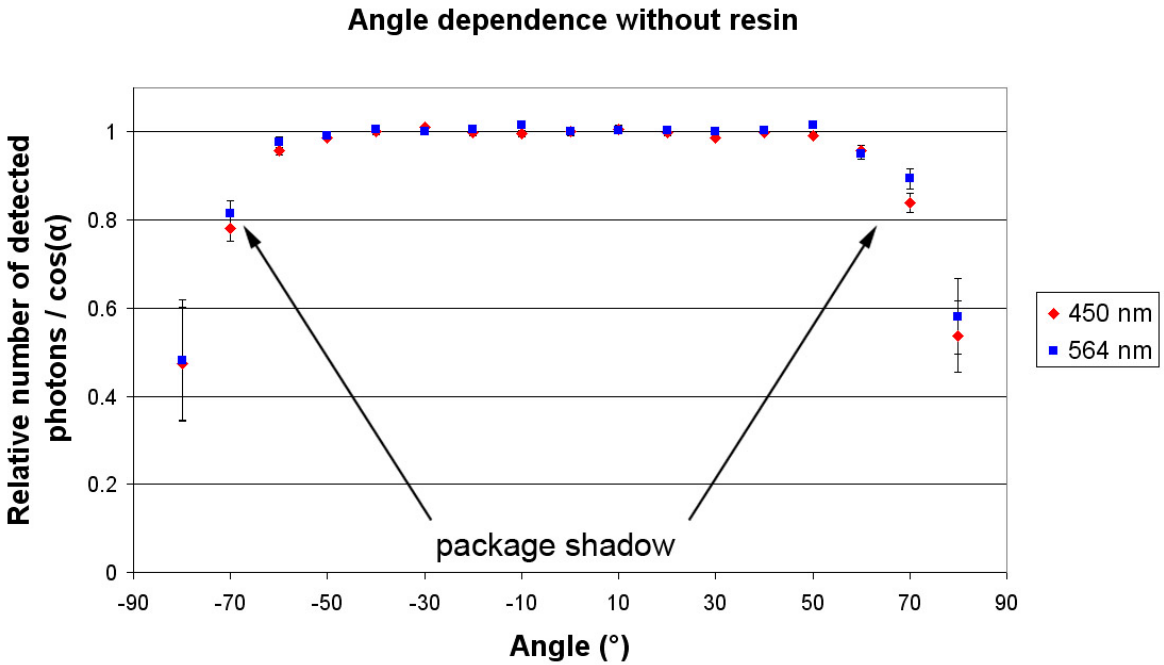
$\Rightarrow$ Afterpulses are not a problem.

Angle dependence

Light concentrators are used to eliminate dead space between the sensitive area (I. Braun *et al.*, OG 2.7, poster 1248). Solid cones allow higher concentration ratios with the cost of larger angles of incidence at the photodetector surface.

But: what is the angle dependence of the PDE?





⇒ No angle dependence found within the measurement error (∼ 1%).

Summary and outlook

- G-APDs are a promising candidate as photodetectors for future IACTs.
- Several properties are favorable compared to PMTs: PDE, afterpulse characteristic, angle dependence, ruggedness...
- Successful operation of a prototype G-APD camera (FACT project) reported this morning (Q. Weitzel *et al.*, talk OG 2.7, 1074).
- A larger camera ($\sim$ 700 pixel) is under development.